

**TRANSMITTAL LETTER TO THE
UNITED STATES
DESIGNATED/ELECTED OFFICE
(DO/EO/US) CONCERNING A FILING
UNDER 35 U.S.C. 371**

ATTORNEY'S DOCKET NUMBER
111252

U.S. APPLICATION NO.
(if known, sec 37 C.F.R.1.5)

09/980393

INTERNATIONAL APPLICATION NO.
PCT/FR00/01660

INTERNATIONAL FILING DATE
June 15, 2000

PRIORITY DATE CLAIMED
June 18, 1999

TITLE OF INVENTION

DEVICE FOR INSTANTANEOUSLY ANALYZING THE SHOT BY SHOT INJECTION DELIVERY SUPPLIED BY AN INJECTION SYSTEM USED IN A COMBUSTION ENGINE

APPLICANTS FOR DO/EO/US

Francois SCHMIDT; Pierre EYNARD; Bernard MAURIN; Christian GAUTHIER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
- ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
- ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
- ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
- ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☒ Entitlement to small entity status is hereby asserted.
16. ☐ Other items or information:

U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) 09/980393		INTERNATIONAL APPLICATION NO. PCT/FR00/01660		ATTORNEY'S DOCKET NUMBER 111252	
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<p>17. <input checked="" type="checkbox"/> The following fees are submitted:</p> <p>Basic National fee (37 CFR 1.492(a)(1)-(5)):</p> <p>Search Report has been prepared by the EPO or JPO\$890.00</p> <p>International preliminary examination fee paid to USPTO (37 CFR1.482)\$710.00</p> <p>No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))\$740.00</p> <p>Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO\$1,040.00</p> <p>International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)\$ 100.00</p> <p style="text-align: right;">ENTER APPROPRIATE BASIC FEE AMOUNT =</p> <p>Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:15%;">Claims</th> <th style="width:15%;">Number Filed</th> <th style="width:10%;">Number Extra</th> <th style="width:15%;">Rate</th> <th style="width:10%;"></th> <th style="width:10%;"></th> </tr> <tr> <td>Total Claims</td> <td>11 - 20 =</td> <td>0</td> <td>X \$ 18.00</td> <td>\$</td> <td></td> </tr> <tr> <td>Independent Claims</td> <td>2 - 3 =</td> <td>0</td> <td>X \$ 84.00</td> <td>\$</td> <td></td> </tr> <tr> <td colspan="3">Multiple dependent claim(s)(if applicable)</td> <td>+ \$280.00</td> <td>\$</td> <td></td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL OF ABOVE CALCULATIONS =</td> <td>\$890.00</td> <td></td> </tr> <tr> <td colspan="4">Reduction by 1/2 for filing by small entity, if applicable.</td> <td>-</td> <td>\$</td> </tr> <tr> <td colspan="4" style="text-align: right;">SUBTOTAL =</td> <td>\$445.00</td> <td></td> </tr> <tr> <td colspan="4">Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 month from the earliest claimed priority date (37 CFR 1.492(f)).</td> <td>+</td> <td>\$</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL NATIONAL FEE =</td> <td>\$445.00</td> <td></td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">Amount to be refunded</td> <td>\$</td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">Charged</td> <td>\$</td> </tr> </table>	Claims	Number Filed	Number Extra	Rate			Total Claims	11 - 20 =	0	X \$ 18.00	\$		Independent Claims	2 - 3 =	0	X \$ 84.00	\$		Multiple dependent claim(s)(if applicable)			+ \$280.00	\$		TOTAL OF ABOVE CALCULATIONS =				\$890.00		Reduction by 1/2 for filing by small entity, if applicable.				-	\$	SUBTOTAL =				\$445.00		Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 month from the earliest claimed priority date (37 CFR 1.492(f)).				+	\$	TOTAL NATIONAL FEE =				\$445.00						Amount to be refunded	\$					Charged	\$		
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a.	<input checked="" type="checkbox"/>	Check No. <u>125510</u> in the amount of <u>\$445.00</u> to cover the above fees is enclosed.
b.	<input type="checkbox"/>	Please charge my Deposit Account No. _____ in the amount of \$_____ to cover the above fees. A duplicate copy of this sheet is enclosed.
c.	<input checked="" type="checkbox"/>	The Director is hereby authorized to charge any additional fees which may be required, or credit any overpayment, to Deposit Account No. <u>15-0461</u> . A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

<p>SEND ALL CORRESPONDENCE TO:</p> <p>OLIFF & BERRIDGE, PLC P.O. Box 19928 Alexandria, Virginia 22320</p>	<p>NAME: William P. Berridge REGISTRATION NUMBER: 30,024</p>
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Date: <u>December 3, 2001</u>	<p>NAME: Thomas J. Pardini REGISTRATION NUMBER: 30,411</p>
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Francois SCHMIDT; Pierre EYNARD; Bernard MAURIN; Christian GAUTHIER

Application No.: U.S. National Stage of
PCT/FR00/01660

Filed: December 3, 2001

Docket No.: 111252

For: DEVICE FOR INSTANTANEOUSLY ANALYZING THE SHOT BY SHOT
INJECTION DELIVERY SUPPLIED BY AN INJECTION SYSTEM USED IN A
COMBUSTION ENGINE

PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office
Washington, D. C. 20231

Sir:

Prior to initial examination and after entry of the Annex to the IPER, please amend
the above-identified application as follows:

IN THE CLAIMS:

Please replace claims 3-7, 11 as follows:

3. (Amended) The measuring device as claimed in claim 1, characterized in that the
means of draining the first measuring chamber (8) comprise a back-pressure regulator (34).

4. (Amended) The measuring device as claimed in claim 1, characterized in that the
means of draining the second measuring chamber (20) comprise a back-pressure regulator
(54) intended to keep the pressure in the second chamber at a reference value.

5. (Amended) The measuring device as claimed in claim 1, characterized in that the
piston (38) is preloaded by a spring (44) urging it toward the second measuring chamber (20).

6. (Amended) The measuring device as claimed in claim 1, characterized in that the
piston (38) moves in a smooth-walled cylinder (36) and in that it comprises an annular
groove (56) open toward the wall of the cylinder (36).

7. (Amended) The measuring device as claimed in claim 1, characterized in that it includes a cooling system for cooling the injector (2), the first measuring chamber (8), the piston (38) and the piston displacement sensor (46).

11. (Amended) The measuring method as claimed in claim 9, characterized in that it consists, when draining the second chamber, in performing this draining until a reference pressure is established in that chamber.

REMARKS

Claims 1 - 11 are pending. By this Preliminary Amendment, claims 3-7 and 11 are amended to remove multiple dependencies. Prompt and favorable examination on the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten claim (37 C.F.R. 1.121(c)(1)(ii)).

Respectfully submitted,



William P. Berridge
Registration No. 30,024

Thomas J. Pardini
Registration No. 30,411

WPB:TJP/kaf

Attachment:
Appendix

Date: December 3, 2001

OLIFF & BERRIDGE, PLC
P.O. Box 19928
Alexandria, Virginia 22320
Telephone: (703) 836-6400

DEPOSIT ACCOUNT USE AUTHORIZATION Please grant any extension necessary for entry; Charge any fee due to our Deposit Account No. 15-0461
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APPENDIX

Changes to Claims:

The following are marked-up versions of the amended claims:

3. (Amended) The measuring device as claimed in ~~of claim 1 or 2~~, characterized in that the means of draining the first measuring chamber (8) comprise a back-pressure regulator (34).

4. (Amended) The measuring device as claimed in ~~one of claims 1 to 3~~ claim 1, characterized in that the means of draining the second measuring chamber (20) comprise a back-pressure regulator (54) intended to keep the pressure in the second chamber at a reference value.

5. (Amended) The measuring device as claimed in ~~one of claims 1 to 4~~ claim 1, characterized in that the piston (38) is preloaded by a spring (44) urging it toward the second measuring chamber (20).

6. (Amended) The measuring device as claimed in ~~one of claims 1 to 5~~ claim 1, characterized in that the piston (38) moves in a smooth-walled cylinder (36) and in that it comprises an annular groove (56) open toward the wall of the cylinder (36).

7. (Amended) The measuring device as claimed in ~~one of claims 1 to 6~~ claim 1, characterized in that it includes a cooling system for cooling the injector (2), the first measuring chamber (8), the piston (38) and the piston displacement sensor (46).

11. (Amended) The measuring method as claimed in claim 9 ~~or 10~~, characterized in that it consists, when draining the second chamber, in performing this draining until a reference pressure is established in that chamber.

1/PRTS

- 1 -

Device for instantaneously analyzing the shot by shot
injection delivery supplied by an injection system used
in a combustion engine

5 The present invention relates to a device for
instantaneously analyzing the shot by shot injection
delivery supplied by an injection system used in a
combustion engine. The injection systems concerned are,
with equal preference, those found in vehicles equipped
10 with a diesel engine, a gasoline engine, or an engine
operating on LPG (liquefied petroleum gas), or any
other type of engine.

Injection systems typically comprise one or
more injection pumps whose task is to place the fuel
15 under a pressure which currently may range from 100 to
2500 bar, one or more pressurized fuel reservoirs, one,
or perhaps more, injectors per cylinder of the engine
to be supplied, and a control system, increasingly
often electronic, whose task is to control the value of
20 the masses or volumes of fuel injected to suit the
conditions of the engine surroundings, the
characteristics of the fuel, and engine running
requirements.

Current trends in injection systems are toward
25 increasing the pressure of the fuel and the precision
with which the injected quantities are controlled.
Attempts are being made at optimizing any parameter
which makes it possible to improve the efficiency of
the engine and reduce the impact that the operation
30 thereof has on the environment, particularly in the
form of gaseous and acoustic pollution.

Measuring devices have been designed to allow
the manufacturers of injection systems and of
combustion engines to develop injectors and make
35 settings and checks on conformity during manufacture
and during installation for end-use.

The known measuring devices are used in
conjunction with a special-purpose test rig, the role

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of which is essentially to turn an injection pump and secure the various elements of the injection system under test. These devices cannot be used on a fuel-injected combustion engine in nominal operation. The measurements are often made using a fluid which differs from the fuel for the injection of which the injection system was designed. That fluid is chosen to exhibit hydraulic properties similar to those of the fuel but with a higher flash point so as to minimize risks of fire and explosion. Thus, in what follows, the term fuel will be used also to denote the fluid used for carrying out delivery measurements.

The measuring apparatus includes a mechanical section and an electronic section. The mechanical section includes a securing system to hold one or more injectors, one measurement cell per injector for producing an electric image of the amount of fluid injected and a system for removing fluid.

The electronic section is generally in the form of a cabinet equipped with various means for interfacing with the operator, such as a screen and a keyboard, and with other external processing systems. The electronic section processes an electrical signal supplied by the mechanical section, controls and drives various auxiliaries concurrent with the measurement process.

The basic technique used for producing such measurement apparatus relies on measuring the displacement of a piston sliding in a liner, the assembly delimiting a deformable measuring volume into which the injected fuel is directed. Any quantity of fuel added to this volume causes a displacement of the piston which can easily be converted into an electrical signal by use of one of the numerous types of sensor available for this purpose. This provides a volumetric measurement. The conversion into a mass measurement is done by calculation, using the value of the density of

the fuel. To guarantee precise calculation, the temperature of the fuel is measured in the measuring volume.

Other methods are used to obtain information of the temporal type, when reference is made to a time scale, or of angular type, when reference is made to a scale associated with the rotation of the driveshaft. There are two methods which are predominantly used. They are based on measuring a variation in instantaneous pressure and are carried out in measuring apparatuses of geometric structure different than those employing a piston. The "Bosch" method uses a long wound tube and the "Zuech" method uses a volume of a few hundred mm³. These methods make it possible to determine at what precise instant fuel is injected, but they give poor precision as to the amplitude of the fuel delivery. These methods therefore do not make it possible to determine precisely the quantity of fuel injected.

The known measuring devices therefore make it possible either to determine precisely the quantity of fuel injected by an injector or to determine the appearance of the curve of the delivery as a function of time. There does not yet exist any measuring apparatus that makes it possible to determine both the precise values of the injected volumes and the injection times/angles.

It is therefore an object of the present invention to provide such a measuring apparatus which therefore makes it possible to perform both these two different measurements.

To this end, the device that the present invention proposes is a device for measuring a quantity of fuel injected by an injector used in a combustion engine comprising a first measuring chamber into which the fuel is injected, a pressure sensor and a temperature sensor respectively measuring the pressure

and the temperature in the first measuring chamber and means allowing this measuring chamber to be drained at least partially, an electronic section controlling the system and analyzing information received through the sensors.

According to the invention, this device comprises, downstream of the first measuring chamber, a second measuring chamber into which the fuel drained from the first measuring chamber is sent, and the volume of the second measuring chamber can vary with the displacement of a piston, the displacement of which is measured using a displacement sensor.

In this way, there is obtained a device which makes it possible to determine the delivery of fluid as a function of time and the precise quantity of fluid injected. The way in which this device works is then, for example, the way described in the paragraph below.

When the device is ready to make a measurement, that is to say when there is fluid in the first and second measuring chambers and a predetermined reference pressure has become established in the first measuring chamber, an injection is performed. This causes an increase in pressure in the first measuring chamber, the increase being associated with the quantity of fluid injected, with the characteristics of the fluid, with the environmental conditions, particularly the temperature, the initial pressure and the volume of the chamber. At the end of injection, the fluid which has been injected is drained into the second measuring chamber. The pressure in the first measuring chamber is thus returned to its initial value and this first chamber is ready to receive a second injection. The fluid which arrives in the second measuring chamber causes the volume of this chamber to increase, pushing the piston. This displacement is measured and, knowing the diameter of the piston, part of the electronic section calculates the exact volume of fluid. This

measurement allows the electronic section to calibrate, at any moment, very exactly, the measurements made by the first measuring chamber.

The first measuring chamber therefore makes it possible to provide, with precision, the "shape" of the injection, while the second makes it possible to measure the quantity of fuel injected. The processing performed by the electronic section makes it possible to compensate for the defects of each of the measurements using the qualities of the other. The mechanical design of the device is more robust than the devices of the state of the art. It is not, in particular, necessary to use a pressure equalizing device in the second measuring chamber. The back-pressure is provided directly by the pressure of injection into the first cell, altering its draining. The piston can therefore simply be returned by a spring. As the stresses in the second measuring chamber are appreciably lower than in a chamber of the same type in the prior art, this chamber has far better resistance and wears far less quickly.

In one advantageous embodiment of the measuring device, a high-speed solenoid valve controlled by part of the electronic section, and a back-pressure regulator are arranged between the two measuring chambers for partially draining the first measuring chamber after an injection until the pressure in the first measuring chamber returns to the pressure that was in this chamber prior to this injection.

In this case, the electronic section advantageously comprises a compensating device to make it possible to take account of any pressure difference there might be in the first measuring chamber after two successive drainings.

In order to be able to drain the second measuring chamber after each displacement of the piston, and thus make measurements always starting from

more or less the same initial piston position, a high-speed draining solenoid valve is advantageously provided downstream of the second measuring chamber.

5 As already mentioned above, the piston may be preloaded, for example by a spring, urging it toward the second measuring chamber.

10 In one advantageous embodiment, the piston moves in a smooth-walled cylinder and comprises an annular groove open toward the wall of the cylinder. This groove makes it possible to trap any leaks of gas or fluid there might be, preventing these leaks from disturbing the measurement. It also makes it possible to make the piston lighter. It also makes it possible to limit the area of the piston that needs to be lapped and matched. Finally, it increases the flexibility of the piston, which allows its sliding in the cylinder to be less impeded.

20 The piston displacement sensor used is, for example, an inductive sensor, but any other type of sensor may be used here. It is possible, for example, also to use an optical sensor, of interferometric type. Such a sensor is more precise, linear, and adds no moving mass to the mass of the piston. By contrast, its cost is higher and it is trickier to operate.

25 The measuring device according to the invention may advantageously comprise a cooling system for cooling the injector, the first measuring chamber, the piston and the piston displacement sensor. Thus, the temperature in the measuring device is evened out and its variations are limited, which makes it possible to increase the precision of the measurements taken. Use is then advantageously made, in the cooling system, of the same fluid as the one used for performing the injections.

35 In any event, the invention will be clearly understood with the aid of the description which follows, with reference to the single appended figure

which depicts, by way of non-limiting example, one embodiment of measuring apparatus according to the invention.

5 The single figure very schematically shows the mechanical part of an apparatus for measuring the quantity of fuel injected by an injector according to the invention.

10 The single figure depicts an injector 2 mounted on an injector support 4. This injector 2 comprises an injection nozzle 6 which lies in a first measuring chamber 8. This measuring chamber is a constant-volume chamber. It is filled with a fluid which has hydraulic characteristics similar to those of a fuel but with a
15 the risks of fire and explosion. This fluid is also the fluid used in the injector 2. A reservoir 10 of this fluid is provided in the device depicted in the drawing.

20 The first measuring chamber 8 has several inlets and several outlets. It has first of all a filling inlet 12, a bleed outlet 14, a high-speed draining outlet 16, and an outlet 18 to a second measuring chamber 20.

25 To fill the first measuring chamber 8, fluid is pumped from the reservoir 10 using a pump 22 driven by a motor 24. A high-speed filling solenoid valve 26 is mounted between the pump 22 and the filling inlet 12 so as to control the filling of the first measuring chamber 8. A solenoid valve 28 is also provided at the
30 bleed outlet 14. To drain the chamber 8, a high-speed draining solenoid valve 30 is provided. It may be pointed out here the high-speed draining outlet 16 is advantageously situated at a low point of the first measuring chamber 8, while the bleed outlet 14 is
35 placed at a high point of this chamber 8.

Arranged between the first measuring chamber 8 and the second measuring chamber 20 are a draining

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solenoid valve 32 and an adjustable back pressure regulator 34.

5 The second measuring chamber 20 has a variable volume. It is produced in a cylinder 36 in which a piston 38 moves. This piston 38 has an end wall 40 and a skirt 42. The end wall 42 is domed and forms a wall closing the measuring chamber 20. To keep the piston 38 balanced, a spring 44 rests against the end wall 40, on the opposite side to the measuring chamber 20. It is just as possible to have a piston with a domed end wall, convex or concave, as it is a piston with a flat end wall.

10 The displacement of the measurement piston 38 is supplied by a displacement sensor 46, engaging at a point of contact 48 with the opposite face of the end wall 40 to the measuring chamber 20. This displacement sensor 46 is, for example, an inductive sensor.

15 The second measuring chamber 20 also comprises a drain port 50, the opening and closure of which are controlled by a draining solenoid valve 52 associated with a back-pressure regulator 54. The drained fluid returns to the reservoir 10. The wall of the cylinder 36 along which the piston 38 travels is a smooth wall. This cylinder may or may not be lined. The skirt 42 on its exterior face has an annular groove 56. This groove extends over roughly half the height of the piston 38 and is centered with respect to the height thereof. This then forms two annular guide surfaces 58.

20 The mechanical device described hereinabove is associated with an electronic device, not depicted here, and which receives information from two temperature sensors 60, each chamber being equipped with a rapid-response temperature sensor 60, and from a pressure sensor 62 located at the first measuring chamber 8.

25 A cooling system is also provided in the measuring device. The cooling fluid is the same as the

fluid injected at the injector 2. Downstream of the pump 22 there is a heat exchanger 64. The same reservoir 10 therefore is used for the fluid injected and for the cooling liquid. This cooling fluid is sent to the injector support 4 and then around the first measuring chamber 8, to the displacement sensor 46 and to the piston 38. An annular chamber 66 surrounds the displacement sensor 46 and comprises a cooling fluid supply duct and a duct for the return of this fluid to the reservoir 10. There is a groove 68 in the injector support 4 to allow the cooling liquid to flow around this injector support. This groove 36 is supplied with cooling liquid by a pipe and the cooling liquid, having left the groove 36, passes into an annular chamber 70 situated around the first measuring chamber 8, before returning to the reservoir 10.

The annular groove 56 of the piston 38 is also supplied with cooling fluid. A supply port is provided in the cylinder 36 for this purpose. Another port is also provided for returning the cooling fluid to the reservoir 10. This return port is advantageously offset heightwise with respect to the supply port and is preferably above the latter and diametrically opposite it.

The way in which this measuring device works is described below.

The first measuring chamber is first of all filled with fluid pumped from the reservoir 10 using the pump 22 and by opening the solenoid valve 26. Once the chamber has been filled, it is bled using the solenoid valve 28, to guarantee that there are no bubbles of air or other gas within it. To fill the second measuring chamber it is possible, during this filling, to open the solenoid valve 32 to the second measuring chamber 20.

To place the first measuring chamber 20 under pressure, fluid is injected through the injector 2 into

the first measuring chamber 8 until a pressure above the reference pressure is obtained. Thanks to the draining solenoid valve 32 and the back-pressure regulator 34, the pressure in the first measuring chamber is returned to the reference pressure. Actual measurement proper can then begin. The injector 2 then injects fluid into the first measuring chamber 8. By virtue of the sensors, particularly the pressure sensor 62, it is thus possible to determine the curve of injected fluid delivery as a function of time. This injection actually causes an increase in the pressure in the first measuring chamber. When the pressure in this chamber is no longer increasing, this fact is used to deduce that injection is finished. The solenoid valve 32 then opens and remains open until the pressure in the first measuring chamber returns more or less to the initial reference pressure. The back-pressure regulator 34 makes it possible to maintain this residual reference pressure in the first measuring chamber 8. The fluid leaving the first measuring chamber 8 is sent into the second measuring chamber 20. The volume of this second measuring chamber 20 therefore increases, and this causes a displacement of the piston 38. The displacement sensor 46 measures this displacement of the piston 38, and by knowing, by virtue of the temperature sensor 60, the temperature of the fluid in the chamber 20, it is possible to determine the quantity of fluid introduced into the second measuring chamber 20.

All the data obtained are then sent to an electronic processing unit. The main data items are the initial pressure in the first measuring chamber, the final pressure in this chamber, and the pressure difference during injection, together with the displacement of the piston 38. Using the "cross matrices" processing method, the results of the measurement are then obtained. These results are

already obtained before a second injection. Indeed, during the first injection, the fluid is injected into the first measuring chamber. Then the fluid is transferred to the second measuring chamber 20. A second injection can therefore take place into the first measuring chamber 8. The results are obtained as soon as the transfer from the first measuring chamber 8 to the second measuring chamber 20 is complete, namely just before the second injection.

The second measuring chamber is drained using the solenoid valve 52. The second back-pressure regulator 54 makes it possible to maintain a second reference pressure in the second measuring chamber 20.

The relationship between the increase in pressure and the volume injected in the first chamber 8 is not linear. It depends in particular on the characteristics of the fluid, on the temperature and on the pressure. This pressure varies during the injection, and this phenomenon is used for the measurement. Calibration is performed by injecting small volumes, but in order to keep precision on the measurement, the volumes are not too small, for example 10 mm^3 for a measurement scale of 200 mm^3 . Several injections are made in succession, beginning the injection at different pressures, chosen to cover the entire range of pressures encountered during nominal operation. Each injection is measured precisely by the second chamber 20. A series of points of correspondence between a starting pressure in the chamber, a small variation in pressure due to the injection and the injected volume is obtained, at the nominal temperature of the measurements with the actual test fluid in its current state. The calculation unit periodically stores a table of values making it possible to linearize and correct, in real time, the subsequent measurements. The advantage of this procedure is that it resorts to no external device. Exploration of the various starting

pressures is done simply by cumulating several injections without opening the solenoid valve for transfer to the second chamber, which has the effect of gradually increasing the pressure in the first chamber 5 8 to somewhere close to each desired value for storing a linearization curve. This method of calibration is given by way of example and other methods are conceivable here.

This measuring device makes it possible to 10 obtain with precision the quantity of fuel injected by the injector and also precisely supplies the curve of delivery as a function of time.

An electronic compensating device is provided to take account of any possible imperfection in the 15 phase of draining the first measuring chamber 8 and to provide precise measurement results even if the final pressure in this chamber, after draining, is not strictly equal to the nominal initial pressure. The system is capable of handling relatively significant 20 variations in this parameter. This compensating function is important because, amongst other things, the response times of the solenoid valve on closure and on opening are not absolutely stable or predictable, even though their mean value is taken into 25 consideration by the system in the sequence for controlling this solenoid valve.

The displacement of the piston measured by the displacement sensor 46, for example an inductive sensor, makes it possible, by knowing the exact 30 diameter of the piston, to calculate the volume injected. This measurement allows the electronic section at any moment to very exactly calibrate the measurements made by the first cell. The groove 56 produced in the piston affords several advantages; 35 first of all, it allows any leaks of gas or fluid there might be to be trapped, preventing these from disrupting the measurement; it also allows the piston

to be lightened and therefore makes it possible to limit the undesirable effects due to its mechanical inertia; and finally it makes it possible to reduce the area of the piston which needs to be perfectly lapped and matched with the interior surface of the cylinder by limiting this guide surface to two rings situated at the ends of the piston. The piston, particularly in the region of its skirt, has greater flexibility than the pistons used in the devices of the prior art thanks to the thinning of the skirt. All this is achieved without making the piston more difficult to produce and in addition while at the same time making it possible to reduce the stresses that impede the sliding of the piston 38 in the cylinder 36.

Because of the design of this system, there is no need to use pressurized nitrogen to provide a back-pressure on the measurement piston. Any risk of leakage of this gas is thus avoided. In addition, the volume and mass of fuel injected at the injector 2 are measured at a stabilized temperature. This brings reliability and precision to the measurement made.

The processing performed by the electronic section pools the information obtained from the two measuring chambers and makes it possible to compensate for the defects of each using the qualities of the other. The results supplied to the operator or to the connected external data processing systems are completely preprocessed by the electronic section and include all compensations.

The mechanical design of this measuring device is far more robust than in the systems of the prior art. In particular, there is no longer any need to use the pressure equalizing device in the first measuring chamber. This back-pressure is supplied directly by the pressure of injection into this chamber by altering its draining. The second measuring chamber with the piston no longer needs to be particularly "quick" because it

is filled by the draining solenoid valve of the first measuring chamber, the operation of which is fully controlled. It no longer needs to operate with a back-pressure, and a simple spring is therefore enough to return it. As the piston operates with lower pressure stresses, the stresses between the piston and its liner are limited, and wear is very significantly reduced.

As goes without saying, the invention is not restricted to the embodiment described hereinabove by way of non-limiting example; on the contrary, it encompasses all alternative forms within the scope of the claims which follow.

CLAIMS

1. A device for measuring a quantity of fuel injected by an injector (2) used in a combustion engine including;
- a first measuring chamber (8) into which the fuel is injected,
 - a pressure sensor (62) respectively measuring the pressure in the first measuring chamber (8),
 - a temperature sensor (60) measuring the temperature in the first measuring chamber (8),
 - downstream of the first chamber (8), a second measuring chamber (20) which is connected to the first chamber (8) by a drain pipe (18) and the volume of which can vary according to the movement of a piston (38), the displacement of which is measured using a displacement sensor (46),
 - means allowing the first (8) and second (20) measuring chambers to be drained at least partially,
 - an electronic section analyzing information received through the sensors (46, 60, 62) and controlling the draining means in particular, characterized in that:
 - the means of draining the first chamber into the second chamber comprise a high-speed solenoid valve (32),
 - the means of draining the second chamber (20) comprise a high-speed solenoid valve (52),
 - the electronic section is designed to control the means of draining the first chamber (8) and the second chamber (20) so as, on the one hand, to partially drain the first measuring chamber (8) after each injection until the pressure in the first measuring chamber returns to

essentially the pressure that was in this chamber prior to this injection and, on the other hand, to partly drain the second chamber (20) after each measurement of the volume of each injection.

2. The measuring device as claimed in claim 1, characterized in that the electronic section comprises a compensating device to make it possible to take account of any pressure difference there might be in the first measuring chamber (8) after two successive drainings.

3. The measuring device as claimed in of claim 1 or 2, characterized in that the means of draining the first measuring chamber (8) comprise a back-pressure regulator (34).

4. The measuring device as claimed in one of claims 1 to 3, characterized in that the means of draining the second measuring chamber (20) comprise a back-pressure regulator (54) intended to keep the pressure in the second chamber at a reference value.

5. The measuring device as claimed in one of claims 1 to 4, characterized in that the piston (38) is preloaded by a spring (44) urging it toward the second measuring chamber (20).

6. The measuring device as claimed in one of claims 1 to 5, characterized in that the piston (38) moves in a smooth-walled cylinder (36) and in that it comprises an annular groove (56) open toward the wall of the cylinder (36).

7. The measuring device as claimed in one of claims 1 to 6, characterized in that it includes a cooling system for cooling the injector (2), the first measuring chamber (8), the piston (38) and the piston displacement sensor (46).

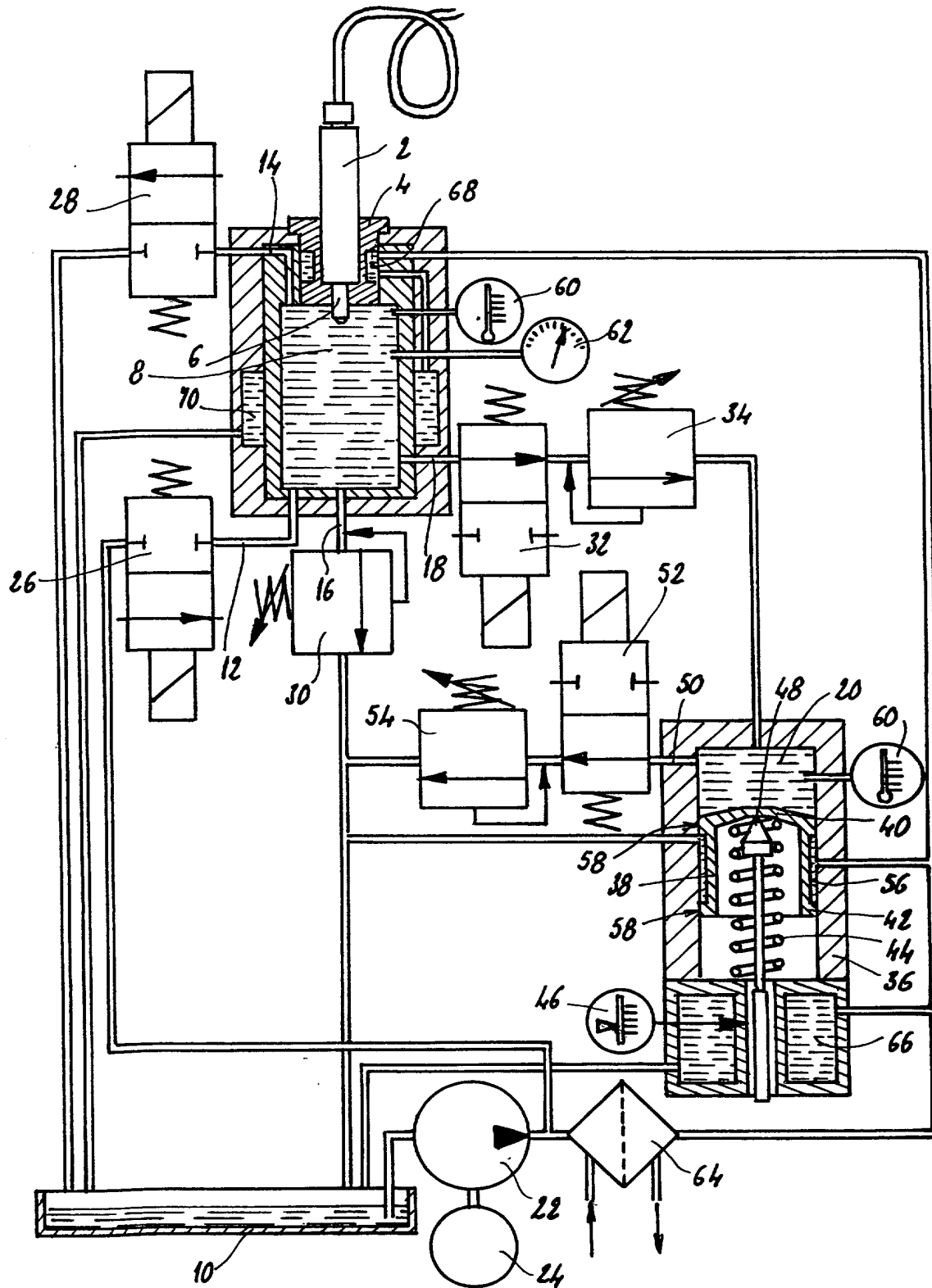
8. The measuring device as claimed in claim 7, characterized in that the fluid used in the cooling

system is the same as the fluid used for performing the injections.

9. A method for measuring characteristics of an injection of fuel performed by an injector of the type consisting in using a first chamber for measuring the pressure and the temperature of injection and a second chamber for measuring the volume of fuel injected, characterized in that it further consists, in particular, for each injection;
- in measuring the pressure and the temperature in the first chamber prior to the injection,
 - in injecting fuel into the first chamber using the injector,
 - during injection, measuring, at least regularly, the pressure and the temperature in the first chamber,
 - at the end of injection, draining some of the fuel contained in the first chamber into the second chamber until the pressure in the first chamber returns roughly to the pre-injection pressure,
 - measuring the volume of the drained fuel and from it deducing the volume of the injection,
 - draining some of the fuel contained in the second chamber.
10. The measuring method as claimed in claim 9, characterized in that it consists in correcting the values relating to each injection using, in particular, prerecorded calibration data.
11. The measuring method as claimed in claim 9 or 10, characterized in that it consists, when draining the second chamber, in performing this draining until a reference pressure is established in that chamber.

Abstract

The measuring device comprises a first measuring chamber (8) into which fuel is injected, pressure sensor (62) and a temperature sensor (60) respectively measuring pressure and temperature in the first measuring chamber (8), means enabling the measuring chamber to be at least partially drained, an electronic section controlling the system and analysing information received from the sensors (46, 60, 62). The device also comprises a second measuring chamber (20) arranged downstream from the first measuring chamber (8). Fuel which is drained from the first measuring chamber (8) is sent to said second chamber. The volume of the second measuring chamber (20) can vary according to the displacement of a piston (38). Said displacement is measured with the aid of a displacement sensor (46).



**DECLARATION AND POWER OF ATTORNEY
UNDER 35 USC §371(c)(4) FOR
PCT APPLICATION FOR UNITED STATES PATENT**

As a below named inventor, I hereby declare that:
my residence, post office address and citizenship are as stated below under my name;

I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought, namely the invention entitled: Device for Instantaneously Analyzing the Shot By Shot Injection Delivery Supplied by an Injection System Used in a Combustion Engine

described and claimed in international application number PCT/FR00/01660 filed June 15, 2000.

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56.

Under Title 35, U.S. Code §119, the priority benefits of the following foreign application(s) filed by me or my legal representatives or assigns within one year prior to my international application are hereby claimed:

French Patent Application No. 99.07982 filed June 18, 1999.

The following application(s) for patent or inventor's certificate on this invention were filed in countries foreign to the United States of America either (a) more than one year prior to my international application, or (b) before the filing date of the above-named foreign priority application(s):

I hereby appoint the following as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent Office:

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ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO OLIFF & BERRIDGE, PLC, P.O. BOX 19928, ALEXANDRIA, VIRGINIA 22320, TELEPHONE (703) 836-6400.

I hereby declare that I have reviewed and understand the contents of this Declaration, and that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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IF THERE IS MORE THAN ONE INVENTOR USE PAGE 2 AND PLACE AN "X" HERE ☒

(Discard this page in a sole inventor application)

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Note to Inventor: Please sign name on line 2 exactly as it appears in line 1 and insert the actual date of signing on line 3.

This form may be executed only when attached to the first page of the Declaration and Power of Attorney of the application to which it pertains.

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